



Overview

Orthostatic Intolerance

Executive Summary

Orthostatic intolerance (OI) is an abnormal response to standing upright caused by an inability to maintain arterial blood pressure and perfuse cerebral tissue. It can result in presyncope and, ultimately, syncope (i.e. loss of consciousness). Specifically in the spaceflight community, OI is a major concern when crewmembers are re-introduced to gravity after landing due to decreased plasma volume and sympathetic nervous system dysfunction. OI must also be considered for standing crew experiencing acceleration loads. A variety of countermeasures can be implemented to reduce the symptoms of and/or completely mitigate OI.

Standards Overview

NASA-STD-3001 Vol. 1

4.2.11 Fitness-for-Duty Orthostatic Hypotension Standard (with Appendix F.10)

All approved countermeasures (fluid loading and compression garments) shall be utilized to mitigate symptoms of orthostatic hypotension (presyncopal/syncopal symptoms) to prevent impacts to performance of critical mission tasks.

NASA-STD-3001 Vol. 2

6.3.2.8 Fluid Loading Water Quantity for Earth Entry [V2 6036]

6.3.2.9 Crew recovery Water Quantity [V2 6037]

7.4.1 Physiological Countermeasures Capability [V2 7038] The system **shall** provide countermeasures to meet crew bone, muscle, sensory-motor, and cardiovascular requirements defined in NASA-STD-3001, Vol. 1.

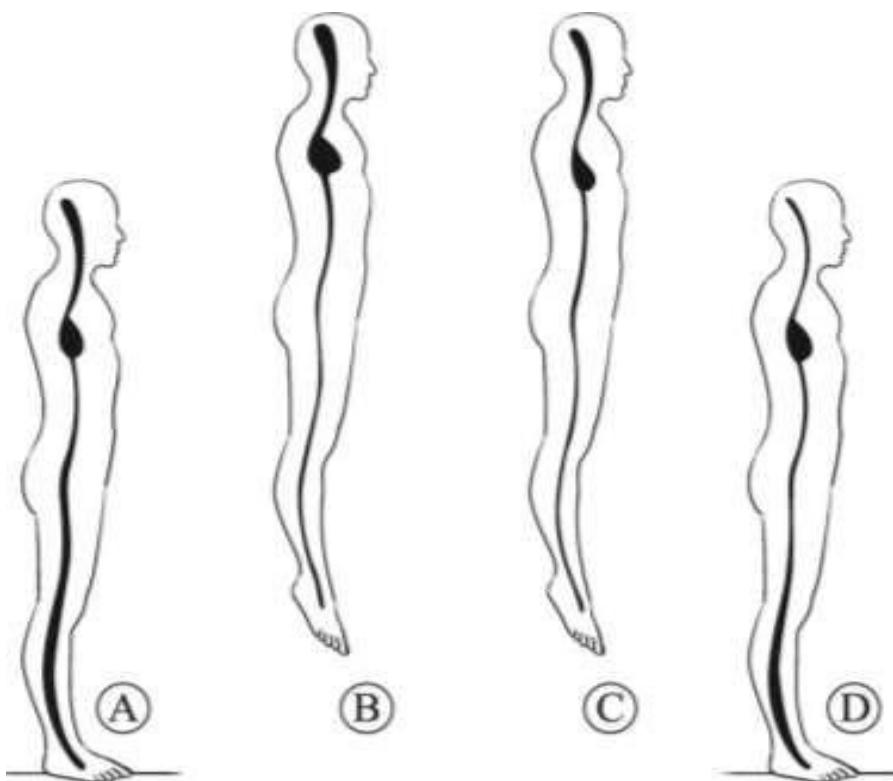
7.4.3 Physiological Countermeasure Operations [V2 7040] The physiological countermeasure system design **shall** allow the crew to unstow supplies, perform operations, and stow items within the allotted countermeasure schedule.

7.4.5 Orthostatic Intolerance Countermeasures [V2 7042] The system **shall** provide countermeasures to mitigate the effects of orthostatic intolerance when transitioning from microgravity to gravity environments.



Background

When crewmembers enter into a microgravity environment, a large number of physiological changes occur, including fluid loss. Below represents a chronological representation of fluid within the body of a spaceflight crewmember:



A: crewmember is on Earth; usual distribution of fluid while standing – excess fluid pooled in the lower body

B: crewmember arrives in microgravity; distribution of fluid is more towards the upper body and head due to absence of gravity and hydrostatic gradient

C: crewmember adapts to the microgravity environment (<2 days) by reducing circulating fluid volume around 15%

D: crewmember returns to Earth; diminished fluid volume and greater percentage in the lower body, giving rise to OI



Application Notes

Several countermeasures can be used to produce a positive effect on OI. The main focuses are increasing venous return or blood/fluid volume. Examples include:

- **Inflight exercise** – aerobic or resistance; used to counteract the cardiac and muscular deconditioning accrued throughout the mission
- **Fluid loading & salt intake** – increased intake of water with sodium chloride the day prior to landing via broth or water + salt tablet; increases plasma volume
 - Currently on ISS, crewmembers drink 24-48 oz of NaCl-water solution before deorbit, depending on their bodyweight
- **Compression garments** – promote venous return via lower body pressure to reduce pre-syncope while standing; e.g. anti-G suit (AGS; left picture), gradient compression garments (GCG; right picture)
 - AGS provides a maximal compression of ~75 mmHg with differential settings
 - Gradient compression garments (GCGs) have greater pressure in the lower leg (~55 mmHg) that gradually decreases throughout the upper leg (~30 mmHg) and abdomen (~20 mmHg); proven to maintain arterial blood pressure and mitigate tachycardia
- **Cooling garments** – to reduce to the heat load experienced by the crew; may have small effects akin to compression garments
- **Pharmaceutical options** – e.g. midodrine, octreotide
- **Artificial gravity** via short radius centrifugation – shown efficacy in bedrest studies, but unknown in spaceflight



These countermeasures have individual viability, but all present limitations. In order to fully protect the crew, several methods should be used in combination to reduce the risk of OI.

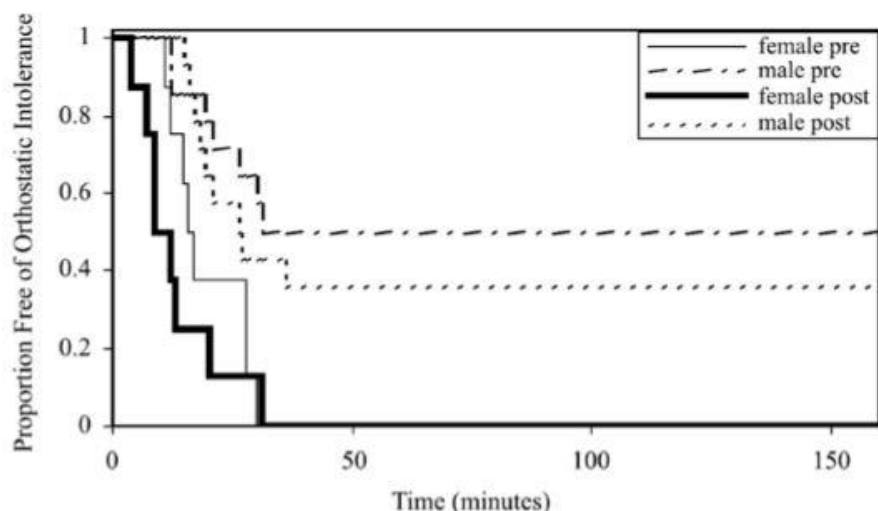
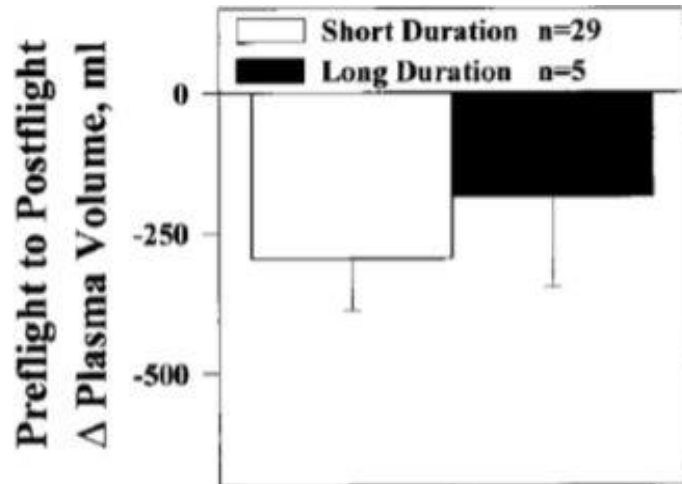


V1 4.2.11, F10

V2 6036-7,7038,7040,7042

Reference Data

- Cephalad (headward) fluid shifts occur when the crew enters microgravity, causing a change in the center of gravity
- Bed rest studies suggest fluid loss occurs within 2 days of being in microgravity
 - 6° head-down tilt bed rest studies have produced similar plasma volume losses (4-17%) to those seen in microgravity
- Apollo program noted decrease in crewmember plasma volume after flight via bodyweight measurements
- Head-down tilt bed rest studies have confirmed (via MRI and EKG) cardiac atrophy occurs within 2 weeks
 - They also confirm autonomic dysfunction, including decreased baroreflex sensitivity
- Large norepinephrine differences are seen between presyncopal and nonpresyncopal hypovolemic test subjects
 - Presyncopal subjects had values similar to normovolemic subjects, but nonpresyncopal subjects had values ~3x compared to normovolemic subjects
- There are marked differences in OI incidence between males and females. Females, generally, do not perform as well in tilt tests and are more prone to OI in the field. This graph (right) exhibits the inequity seen between sexes before and after a bed rest study. ~50% of women were presyncopal at 10 minutes with a 30° tilt, compared to 0% of men.



References

Evidence Report: Risk of Orthostatic Intolerance During Re-exposure to Gravity – HRP, HHCE

Space Operations Medical Support Training Course – SMO Division

Risk of Orthostatic Intolerance during Re-exposure to Gravity – Stuart Lee (HSRB presentation on 9/12/2019)

NASA Office of the Chief Health & Medical Officer (OCHMO)

This Technical Brief is derived from NASA-STD-3001 and is for reference only.

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